Feasibility Study of Integrating IDELIX's Pliable Display Technology into the COPlanS Technology Demonstration Software

Issue Number:	Version 1
Issue Date:	March 31, 2005

The contents of this document are subject to change

Report Documentation Page					Form Approved OMB No. 0704-0188
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE **MAR 2005**		2. REPORT TYPE			3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Feasibility Study of Integrating IDELIX's Pliable Display Technology into the COPlanS Technology Demonstration Software**					5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)					5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Defence R&D Canada -Ottawa,3701 Carling Ave,Ottawa Ontario,CA,K1A 0Z4**					8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)					10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**					
13. SUPPLEMENTARY NOTES **The original document contains color images.**					
14. ABSTRACT **This document examines the potential for enhancement of Defence Research and Development Canada's Collaborative Operations Planning System (COPlanS) technology demonstration software in the areas of collaboration and data visualization using IDELIX's Pliable Display Technology. In particular, it begins by outlining several possible forms of general collaboration that apply to the application and then defines a number of areas within the application with collaboration and data visualization improvement potential. Each of these areas is subsequently analyzed in depth with specific details of how enhanced collaboration and data visualization can be attained with PDT. Finally, rough orders of magnitude are provided for all defined features and potential implementation approaches.**					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**43**	

Table of Contents

1.ABSTRACT ... **4**

2.INTRODUCTION ... **5**

3.POTENTIAL ENHANCEMENTS TO COPLANS ... **6**

3.1.Collaboration ... 6
3.2.Collaboration in COPlanS ... 6
3.3.Natural COPlanS Collaborative Capabilities ... 7
3.4.COPlanS Enhancement Options ... 7

5.GENERAL VISUAL COLLABORATION ... **8**

5.1.Visual Highlighting Approaches for Multiple Users ... 8
5.1.1.Remote Cursors ... 8
5.1.2.Multi-User Radar View ... 8
5.1.3.Awareness Lenses ... 8
5.1.4.Universal Annotation ... 8
5.1.5.Central Note Board ... 8
5.2.Synchronization Approaches for Two Users ... 8
5.2.1.Multi-User Master/Slave Synchronization ... 8
5.2.2.On-Demand Synchronization ... 9
5.3.Architectural Considerations ... 9

6.PDT IN THE COPLANS GIS ... **10**

6.1.On-Map Mission Planning ... 11
6.2.PDT Enhancement of On-Map Mission Planning ... 11
6.2.1.PDT Lens Providing Focus plus Context ... 12
6.2.2.Lens-assisted Functionality ... 14
6.2.3.Snail Trails ... 15
6.2.4.De-cluttering of a Mission Planning Map ... 15
6.3.Collaboration ... 16

7.PDT IN THE COPLANS GIS OPERATING ON A COLLABORATION TABLETOP ... **17**

7.1.Collaboration Tabletop ... 17
7.2.The MERL DiamondTouch Table ... 17
7.2.1.Target Users and Scenarios for the DiamondTouch Table ... 17
7.2.2.Currently Available DiamondTouch Table Aware Applications ... 18
7.2.3.Pliable Display Technology and the DiamondTouch Table ... 18
7.2.4.A Table Aware Software Application ... 18
7.2.5.Functionality of a Table Aware Application ... 18
7.2.6.Software Functionality Requirements for a Table Aware Application ... 18

8.ENHANCING THE VISUAL DIAGRAMMING COMPONENTS OF COPLANS ... **21**

8.1.Workflow Management ... 21
8.2.Mission Analysis ... 22
8.3.Order of Battle (ORBAT) Asset Visualization ... 23
8.4.Detail-in-Context for Visual Diagramming in COPlanS ... 24

9.ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATES BY FEATURE ... **25**

9.1.General Visual Collaboration ... 25
9.1.1.Visual Highlighting Approaches for Multiple Users ... 25
9.1.2.Synchronization Approaches for Two Users ... 26
9.3.PDT in the COPlanS GIS (Note: Assumes access to GIS source code) ... 27
9.3.1.PDT Lens Providing Focus plus Context ... 27

9.3.2. *Lens-assisted Functionality* ... 27
9.3.3. *Snail Trails* ... 27
9.3.4. *De-cluttering of a Mission Planning Map* ... 27
9.4. PDT in the COPlanS GIS Operating on a Collaboration Tabletop (Note: Assumes access to table aware GIS application source code) ... 28
9.4.1. *Multi-user (vs Single-user turn taking)* ... 28
9.4.2. *Pliable Display Technology* ... 28
9.4.3. *Geo-spatial Capabilities* ... 28
9.4.4. *Mensuration* ... 28
9.4.5. *Tool Bars (Specialized Tabletop)* ... 28
9.4.6. *Layers and Transparency* ... 28
9.4.7. *Remote Collaboration* ... 29
9.6. Enhancing the Visual Diagramming Components of COPlanS ... 30
9.6.1. *Enhancement of Workflow Diagrams* ... 30
9.6.2. *Enhancement of Effect Based Diagrams (Mission Analysis)* ... 30
9.6.3. *Enhancement of ORBAT Charts* ... 30

10. IMPLEMENTATION MODELS ... 31

10.1. OEM Integrates Required Functionality ... 31
10.2. OEM Provides APIs to the Image Processing Pipeline; IDELIX Integrates ... 31
10.3. OEM and IDELIX Jointly Integrate Required Functionality ... 31
10.4. IDELIX Integrates Required Functionality ... 31
10.5. Third Party System Integrator Integrates Required Functionality ... 31
10.6. IDELIX Produces an Application to Specification ... 31
10.7. Third Party System Integrator Produces an Application to Specification ... 31

11. ROUGH ORDER OF MAGNITUDE (ROM) ESTIMATES BY IMPLEMENTATION MODEL ... 33

11.1. General Visual Collaboration ... 33
11.1.1. *Multi-User Master/Slave Synchronization for 2 Users – Dumb Display Host* ... 33
11.1.2. *Multi-User Master/Slave Synchronization for 2 Users – Application Synchronization* ... 34
11.3. PDT in the COPlanS GIS ... 35
11.3.1. *PDT Enhancement of On-Map Mission Planning* ... 35
11.5. PDT in the COPlanS GIS Operating on a Collaboration Tabletop ... 38
11.5.1. *Software Functionality Implementation for a Table Aware Application* ... 38

12. POINTS OF CONTACT ... 40

12.0.1. *Business Contacts* ... 40
12.0.3. *Technical Contacts* ... 40

1. Abstract

This document examines the potential for enhancement of Defence Research and Development Canada's Collaborative Operations Planning System (COPlanS) technology demonstration software in the areas of collaboration and data visualization using IDELIX's Pliable Display Technology. In particular, it begins by outlining several possible forms of general collaboration that apply to the application and then defines a number of areas within the application with collaboration and data visualization improvement potential. Each of these areas is subsequently analyzed in depth with specific details of how enhanced collaboration and data visualization can be attained with PDT. Finally, rough orders of magnitude are provided for all defined features and potential implementation approaches.

2. Introduction

The purpose of this document is to outline how the Collaborative Operations Planning System (COPlanS), developed by Defence Research and Development Canada Valcartier (DRDC Valcartier), can be enhanced through the use of improved collaboration techniques and visualization methods using IDELIX's Pliable Display Technology (PDT).

It is assumed that the reader is familiar with the COPlanS application and has a basic understanding of how IDELIX's PDT works.

3. Potential Enhancements to COPlanS

3.1. Collaboration

Traditionally, software was developed with a single user in mind. However, with the increase in network capabilities, software support for multiple users has become more widespread. A major difficulty in the design of such software is that the requirements for a collaborative system are often quite different than those for a single user system. Designing software for a collaborative environment is difficult.

When considering collaboration in the design of a software system, it is useful to realize that there are different kinds of collaboration that may be supported. These kinds of collaboration lie along two axes, namely time and space, with two values along each axis resulting in 4 different collaboration scenarios (see Figure 1 below). Supporting collaboration in these different situations often requires differences in design.

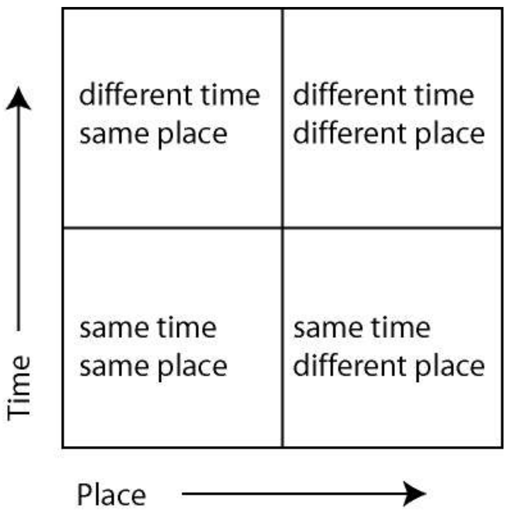


Figure 1 – Different Kinds of Collaboration

Some examples of collaboration that fit into the 4 categories are:

1. Same time, same place:
    a. Users working together on a tabletop display.
    b. Users working together on an electronic whiteboard.
    c. Users gathered around a single computer.

2. Same time, different place:
    a. Users working on their individual computers, collaborating over the internet.
    b. Users working on their individual computers, talking on the phone.

3. Different time, different place:
    a. Users sending email to one another asking questions about a project.
    b. Users copying files over to a central repository, to be accessed later by somebody else at a different location.

4. Different time, same place:
    a. Users leaving notes on a tack-board for one another.
    b. Users drawing comments on a large printed diagram, to be seen later by somebody else.

3.2. Collaboration in COPlanS

The COPlanS system is a very complex piece of software, supporting a very complex planning process involving many people. Currently, activities such as on-line planning, video teleconferencing, on-line chatting and on-line white boarding are all supported by the application while future versions will potentially add interactive war gaming, mission rehearsal and synthetic environments to the list of its collaborative features. However, the model for COPlanS interaction seems to be based upon the interaction model that existed prior to the development of the COPlanS system. An attempt has been made for established real-world interactions, be they voice communication, paper-based notes, or computer-based communications, to have equivalents designed into the COPlanS system. For example, maps, which may have previously existed as large paper maps or electronic maps shown on a dedicated computer viewing system, are shown in their own sub-window in COPlanS.

Modeling COPlanS interactions on previously established interactions is extremely valuable in order to allow users to adjust to the system. However, a designer must be careful to not abandon previously available, and potentially critical, forms of collaboration. For example, it is possible for several people to gather around a large paper map pinned onto a wall and discuss a problem but it is much more difficult for multiple people to gather around a small computer monitor. The affordances of these two systems are remarkably different, meaning they naturally encourage and support different types of behaviour. When affordances differ between a predecessor system and a successor system, a designer must design the new system in such a way as to make up for lost capabilities.

It is thus desirable for special collaboration capabilities to be built into COPlanS. These capabilities could be used to mimic or compensate for lost collaboration capabilities not naturally supported by the COPlanS interaction model. These capabilities could also make possible new forms of collaboration that were not possible prior to the existence of COPlanS.

3.3. Natural COPlanS Collaborative Capabilities

The basic COPlanS architecture is based on a centralized database of knowledge that is accessible to all interested users. This architecture naturally supports two of the kinds of interaction shown in Figure 1, namely the two cases where collaboration is distributed across time. Since data is stored centrally, changes made by one user are automatically made available to other users who access the data later. The centralized data store is constantly up to date, and regardless of what point in time a user logs on, they are up to date, and ready to work.

Since collaboration across time is naturally supported by the existing COPlanS architecture, it is useful to focus on the current weak-point of COPlanS, namely simultaneous collaboration, either in one place, or spatially distributed. Simultaneous collaboration is a capability that is not naturally supported by the COPlanS architecture.

3.4. COPlanS Enhancement Options

Below are a number of areas where COPlanS can potentially be enhanced as well as a subset where PDT can assist with collaboration by providing improved visualization of the information being presented:

- General Visual Collaboration
- PDT in the COPlanS GIS
- PDT in the COPlanS GIS Operating on a Collaboration Tabletop
- Enhancing the Visual Diagramming Components of COPlanS
    - Workflow Management (Workflow Diagrams)
    - Mission Analysis (Effect Based Diagrams)
    - Order of Battle Asset Visualization (ORBAT Charts)

4.

5. General Visual Collaboration

5.1. Visual Highlighting Approaches for Multiple Users

A number of approaches to providing visual highlighting for collaboration purposes among multiple users are discussed below. The approaches range from the simple use of remote cursors to the more complex use of a universal annotation tool.

5.1.1. Remote Cursors

When multiple users are working simultaneously, but remotely, they may need to develop an awareness of what the remote users are doing. This can be done by showing cursors of remote users moving over the screen of a local user. A local user would have his own cursor with which to interact with data, but he would also see “ghost” cursors representing the current actions of remote users. However, a question arises as to what to show when the screen content of a local user is different from that being shown on a remote user’s desktop. For example, a remote user may be working on a map, while the local user may not have the map visible. Thus, it is proposed that a remote user’s cursor only be shown if the cursor is over content that is currently visible to the local user.

5.1.2. Multi-User Radar View

Cursors, as previously described, can give some level of awareness as to the actions and intentions of remote users. There are also other ways to promote awareness. One way is to offer a sort of “awareness map” that displays the locations of multiple users in a large display space, such as a map. When remote users are collaborating simultaneously in a large display space, they will frequently navigate to different parts of the display space. This can result in confusion if they assume that they are looking at the same area. A map of the entire display space with individual rectangles indicating individual user locations can be used to communicate to different users the views of their collaborators. This reduces confusion, improves efficiency, and reduces the occurrence of errors.

5.1.3. Awareness Lenses

Lenses could be used for promoting awareness of the actions of remote users. In much the same way as cursors were suggested for use above, lenses would provide a local user with hints as to what remote users were doing. Two advantages of using lenses are the fact that lenses can provide a detailed view of the actions of remote users and a local user would be unlikely to confuse his cursor with a remote controlled lens.

5.1.4. Universal Annotation

When multiple users are working together remotely, whether simultaneously or at different points in time, it is often useful to be able to make ad-hoc comments regarding any part of the data being operated on. This commentary can take any form. Therefore, it is desirable to provide absolute flexibility in what form these comments can take. It is suggested that COPlanS offer the capability of marking up data with “virtual crayons” that function as crayons would on a piece of paper. A user could scribble text or diagrams anywhere within the context of the data. These notes could then be accessed by any other user and possibly deleted or modified by other users as well.

5.1.5. Central Note Board

A central shared note board could be used for making comments that need to be read by other users but do not fit into any of the standard workspaces for whatever reason.

5.2. Synchronization Approaches for Two Users

5.2.1. Multi-User Master/Slave Synchronization

Sometimes it can be desirable for two remote users to have their remote applications tied together. In this situation the two applications would be in identical states at all times. The two users would be able to either simultaneously control the workspace, or pass control to one another using some protocol.

Synchronization of this sort serves to minimize confusion and can be useful if one user wants to provide a second remote user with a “walk-through” of a situation.

The mechanism for synchronizing two systems can take one of two forms. In the first form, the slave machine would be a dumb display host, essentially receiving screenshots over the network from the master. The main advantage to this approach is that it is relatively easy to implement while the main disadvantage is that it is highly bandwidth dependent. The alternative is for the two systems to be synchronized via messaging of the application state. System state synchronization could be achieved by sending mouse events over the network or by explicitly setting the state of application components. The advantage of this approach is conservation of bandwidth while the disadvantage is the complexity of the synchronization process.

5.2.2. On-Demand Synchronization

While the previous example dealt with prolonged system synchronization, it could be useful to have the option of performing a one-time system synchronization. In this scenario, a user would request the software to synchronize to the state of a remote collaborator. The system would immediately put the software in a state identical to that of the collaborator. Immediately after this action, however, control would be returned to the user and the user would be free to navigate away from this original state without any impact on the state of the remote collaborator’s system. This function would be useful if two collaborators wanted to start with the same initial state but then wanted to work in parallel.

5.3. Architectural Considerations

The example collaboration scenarios described above require that COPlanS be able to provide efficient communication between users, made possible by efficient communication between users’ machines. In order for awareness to be improved, tools such as remote cursors, awareness lenses, and others necessitate up to date display of relevant data. If components meant to promote awareness and collaboration are out of date, due to bandwidth or latency issues, awareness and collaboration may in fact be hampered.

There are two main possibilities when considering communication, either a TCP/IP based client/server architecture or a TCP/IP based peer-to-peer architecture. Considering the existing COPlanS architecture, which is client/server, it would seem natural for collaboration functions to also be client/server in nature. In fact, this would be ideal for such suggested functionality as the central note board, universal annotation, remote cursors, and multi-user radar views. All of these examples can potentially involve many users, rather than just two. A peer-to-peer architecture would also be possible but would require a web of many constantly open network connections. Also, a centralized client/server architecture would minimize the need for complicated synchronizations. It is useful to note that a centralized client/server architecture puts great reliance on reliable connections. It should be safe to assume reliable networking for the purpose of the proposed collaboration functionality, since reliable networking would be a requirement for basic functioning of COPlanS anyway.

For the case of functionality involving only two users, such as on-demand synchronization and master/slave synchronization, a client/server architecture is not such a clear choice. For this functionality, a central server would only serve to insert an extra step in communication, which could be an unnecessary performance bottleneck. For two-user collaboration, a direct peer-to-peer connection may be more appropriate. Response time would be faster, and bandwidth could possibly improve.

6. PDT in the COPlanS GIS

The amount of information available to the war fighter has increased dramatically in recent years. This increase in the quantity of information has not necessarily led to improved situational awareness and better decision-making. The complexity of the modern battlefield is such that problems of interoperability, collaboration, correlation, fusion, and overload are replacing the old problem of insufficient information.

One of the key functionalities offered by COPlanS is a GIS. In using the GIS the resolution of an image often exceeds that of the display. Information is seemingly lost as data is taken out of context by traditional viewing methods such as zooming, panning, or using separate or inset views. Each of these approaches disconnects the area of interest from the underlying information, thus inviting errors in interpretation. As data density continues to increase and display screens get smaller, innovations in visualization software and data interaction are necessary to ensure timely, accurate military decisions are being made.

Using a magnifying lens metaphor, detail appears within the center of the PDT focal region and blends smoothly into the background context using the lens periphery or shoulder. Once PDT is integrated within a host application, tools commonly used to perform editing, annotation, or other data interaction functions can be applied with complete accuracy to the information appearing within the lens. PDT replaces recurring zooming and panning steps and the use of inset windows that result in workflow inefficiencies and important information being pushed off the screen or hidden from view. Additionally PDT facilitates new visualizations such as area specific blending and collaboration.

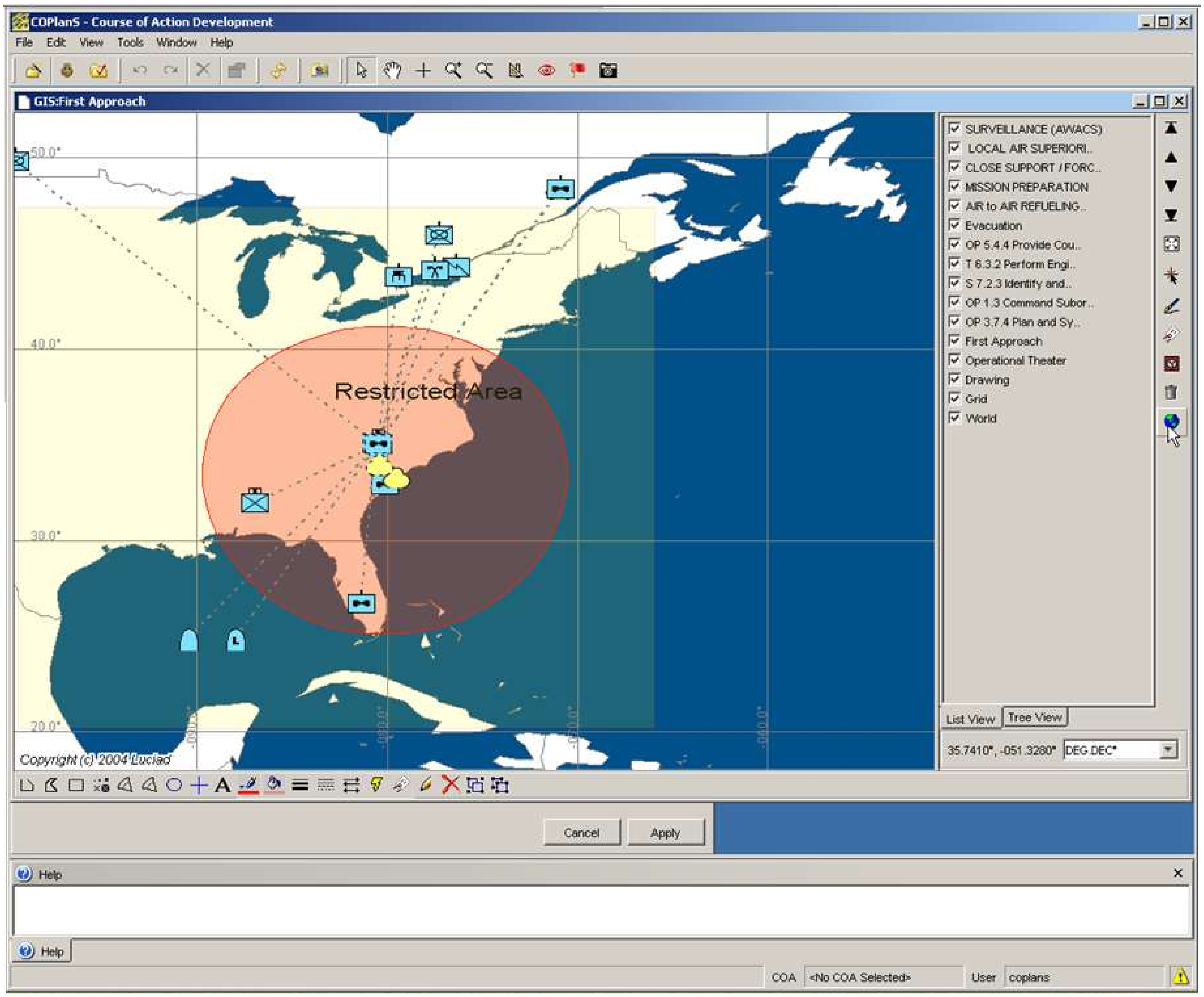


Figure 2 – Cluttering of the GIS Mission Planning Map

6.1. On-Map Mission Planning

The GIS mapping tool is one of the most essential components of the COPlanS application since much of the Coarse of Action (COA) sketching and planning is map-based. Viewing stacks of GIS layers and military symbols can make the screen appear cluttered and confusing (see Figure 2 above). Existing zooming and panning tools don't properly address the need to analyze a detailed region of interest on a map and understand how this detail relates to the context of the surrounding image. Standard inset views are also highly problematic in that they hide information and break visual continuity with the surrounding context outside the area of interest.

6.2. PDT Enhancement of On-Map Mission Planning

The benefits of integrating PDT into the GIS component of the COPlanS application are numerous and compelling. First, PDT extends traditional zoom and pan capabilities by allowing users to view detail within a region of the map without loosing a view of the surrounding context. The magnified area and the background map remain seamlessly connected. Second, PDT can help users view multi-layer GIS data while conserving communication bandwidth between the application viewer and the base GIS data. To reduce data download time the PDT-enhanced application would only request data for the relevant area of interest (i.e. the area currently covered by the lens). The integration of PDT also makes it possible to view different layers and combinations of layers within the lens from the layer being displayed in the base image. Finally, PDT's unique "undisplace" feature permits accurate distance measurement and symbol placement within a PDT lens thereby eliminating time consuming and inefficient zooming and panning.

The following sections describe, in detail, PDT related functionality that can potentially be integrated into the GIS component of the COPlanS application.

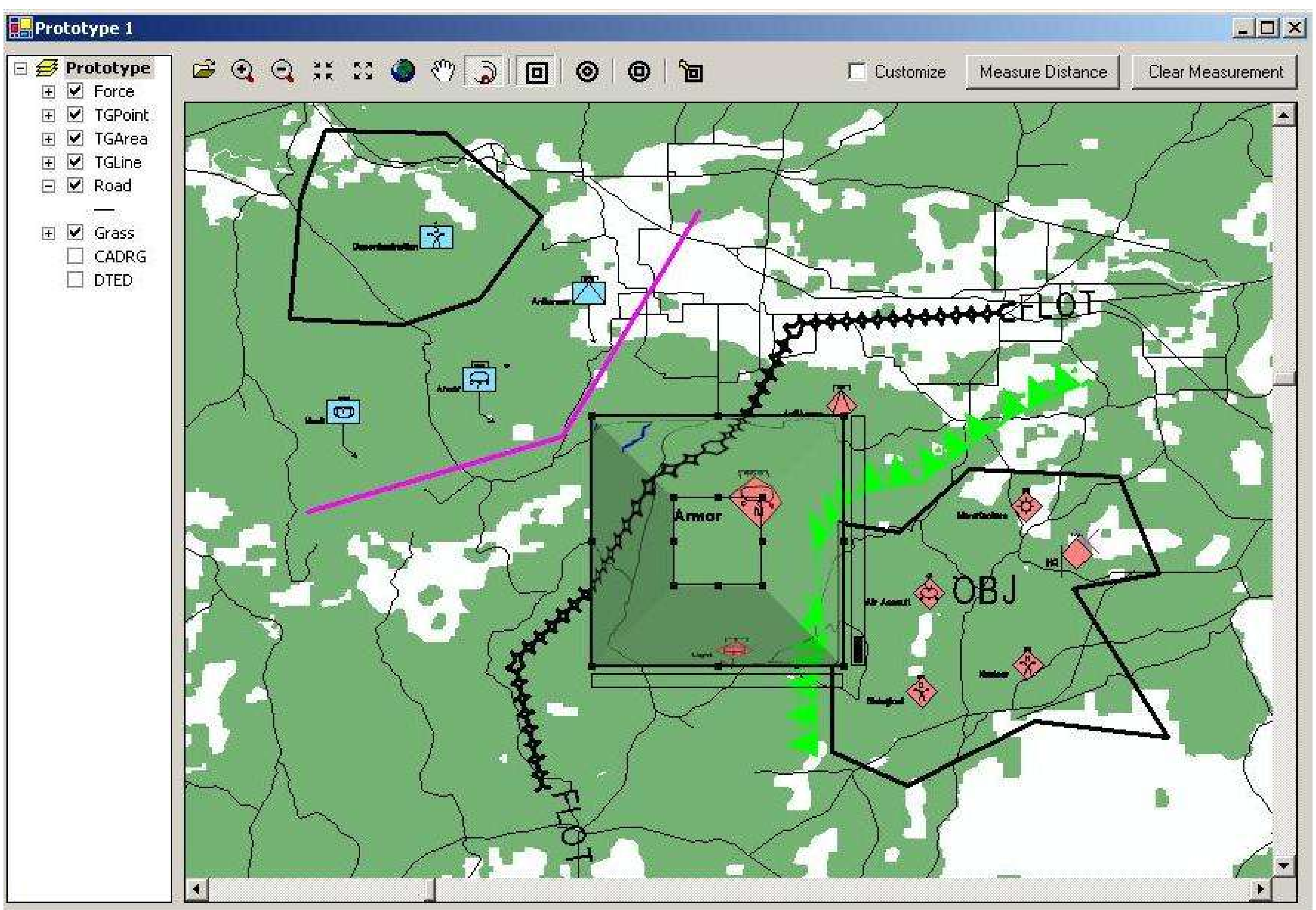


Figure 3 – PDT Lens on a Map

6.2.1. PDT Lens Providing Focus plus Context

PDT is a powerful alternative to existing zooming and panning tools. PDT lenses represent an enhancement to the GIS client application user interface for rapid exploration of large geo-spatial areas and for providing local detail with full situational awareness without hiding information. PDT's user interface provides the user with direct and intuitive control over the presentation of data within the lens (see Figure 3 above).

6.2.1.1. Lens Control

The following PDT lens controls can be implemented:

- Modular Design Lens Control (MDLC) including magnification slider, scoop slider and user resizing via point, click and drag.

The end user would be able to change the parameters of each lens by using the associated MDLC, independent of other lenses on the same image. The end user would be able to configure each occurrence of the lens as follows:

- MDLC controls are always visible
- MDLC controls are only visible when lens is selected

6.2.1.2. Lens Shapes and Lens Creation

First, the following PDT lens shapes can be implemented and made selectable by the end user when the lens is being added to an image.

- Pyramid
- Cone
- Square

e shape of an existing lens can be configured to be changeable. Third, when a lens is selected it can be made to appear tically centred on the screen viewing area of the image. In addition, it is possible to enable the end user to pre-configure the ze, magnification level, MDLC colours, scoop setting) since these settings are saved on the target machine and applied to all users and images. Also, when a lens is subsequently placed on an image, the lens can be sized as per the "pre-red size" as described above. Finally, the end user can be allowed to selectively remove each lens uniquely from an image.

dering Options

ct to image rendering the user can be given control over image warping, image shading and image anti-aliasing. The three options for image warping are the triangle, fast and pixel warpers. The triangle image warper produces a more accurate and detailed image than the fast image warper. However, on computers with slow CPU's the motion of the lens can be jerky when using the triangle image warper. Thus, in order to improve lens response while it is being moved, the fast image warper should usually be used in these situations. Both image shading and image anti-aliasing can be either turned on or turned off.

der to provide a set of user-friendly controls over image rendering, the following image warping, shading and anti-aliasing options can be implemented:

uality (using pixel image warping, shading and anti-aliasing,

ality/Performance (using pixel image warping only), and

ce (using fast image warping only).

ons

lens options that can be included:

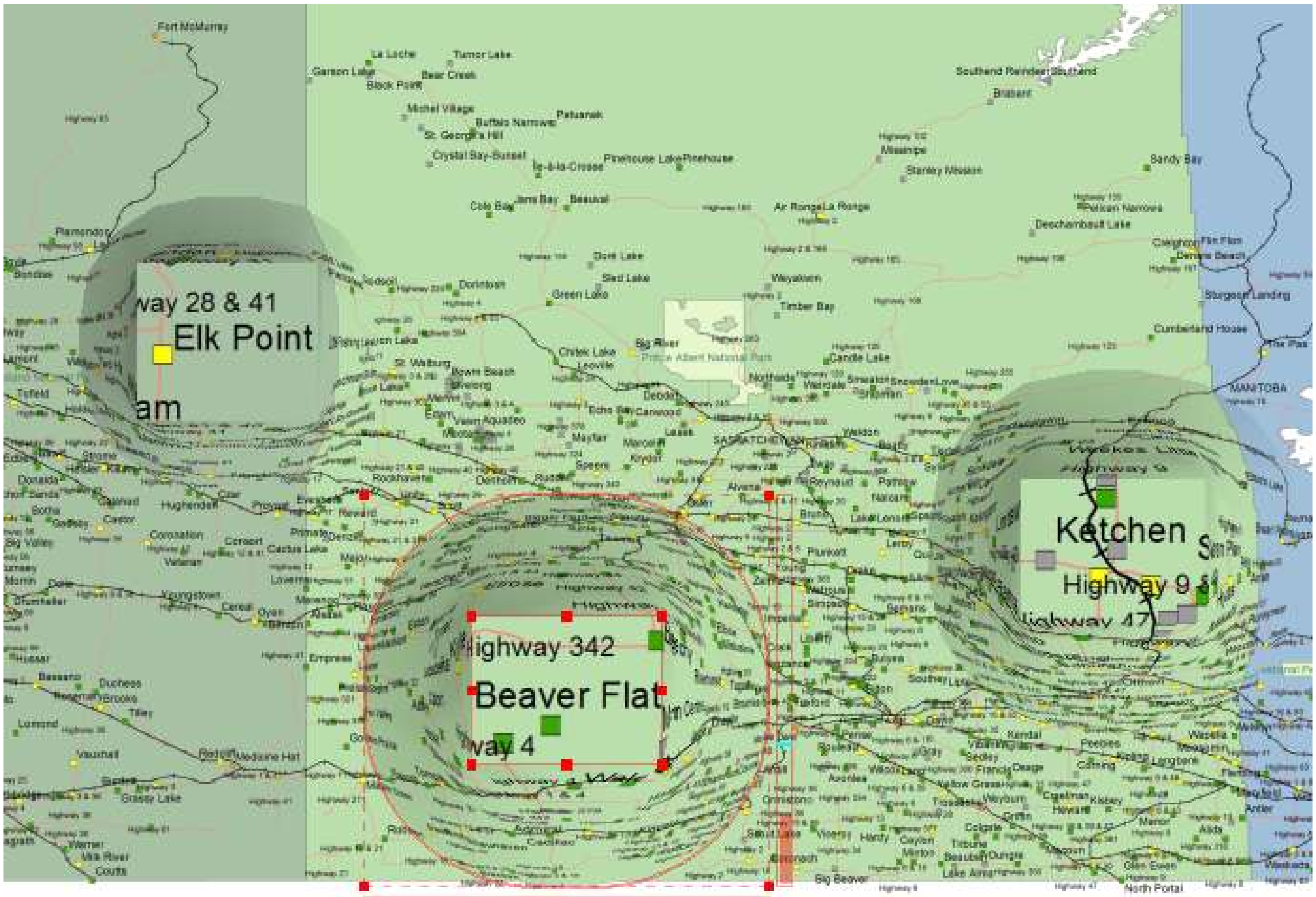
n or off when moving lens

rols for selected lens

for non-selected lenses

pported

nses. These lenses can highlight multiple areas of interest, perform precise point-to-point measurements without panning, and on (See Figure 4 below).



s on a Map

e supported on a single image. The only limit would be one based upon the amount of memory on the user's computer.

e to support folding. The user can also be given the ability to "unfold the lens" through the single click of a GUI button.

ile a Lens is on an Image

tool can be maintained. In addition, when an image is panned, the PDT lens can be configured to remain locked to the image cked to the screen where placed, or disappear.

ile a Lens is on an Image

n tool can be maintained. Also, when one or more PDT lenses are on an image and the user globally zooms the image, the maintain their sizing relative to the screen. In addition, when the image is zoomed, the magnification of the lens can be he image within the lens will change as a function of the global zoom times the zoom setting of the lens. And finally, when an DT lens can be configured to remain locked to the image where placed, locked to the screen where placed, or disappear.

nade available in the GIS portion of the application.

bility, through an easy to use UI, to zoom the entire image to the scale of the focal region of a PDT lens.

MDLC controls can be rendered invisible with an indication that the image has been zoomed in.

llowed to increase or decrease the zoom level of the image.

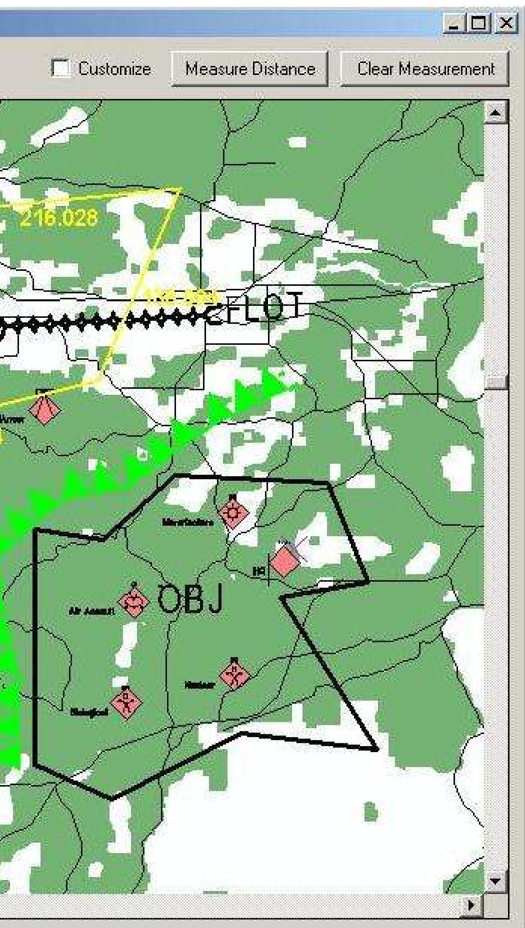
n be allowed to reverse the zoom to scale operation previously executed.

an be made to remain operational.

sitioned to be consistent with the zoomed in image and the MDLC controls can be made visible.

e level of magnification prior to zooming out even if the user had changed the zoom level while zoomed to scale.

pically faced with many unnecessary navigation steps when using these tools at an adequate scale for precise data authoring. PDT, where symbols can be "dropped" into place precisely, while eliminating the need for zooming and panning. PDT speeds atial production workflow.



the user to perform fully precise distance measurements spanning a large extent of the data without the need for awkward length, perimeter, and radius measurements within the GIS application can similarly benefit when the measuring tool is y to turn on and off a shaded snail trail (that will show where the PDT lens has been on the image) as well as clear the snail

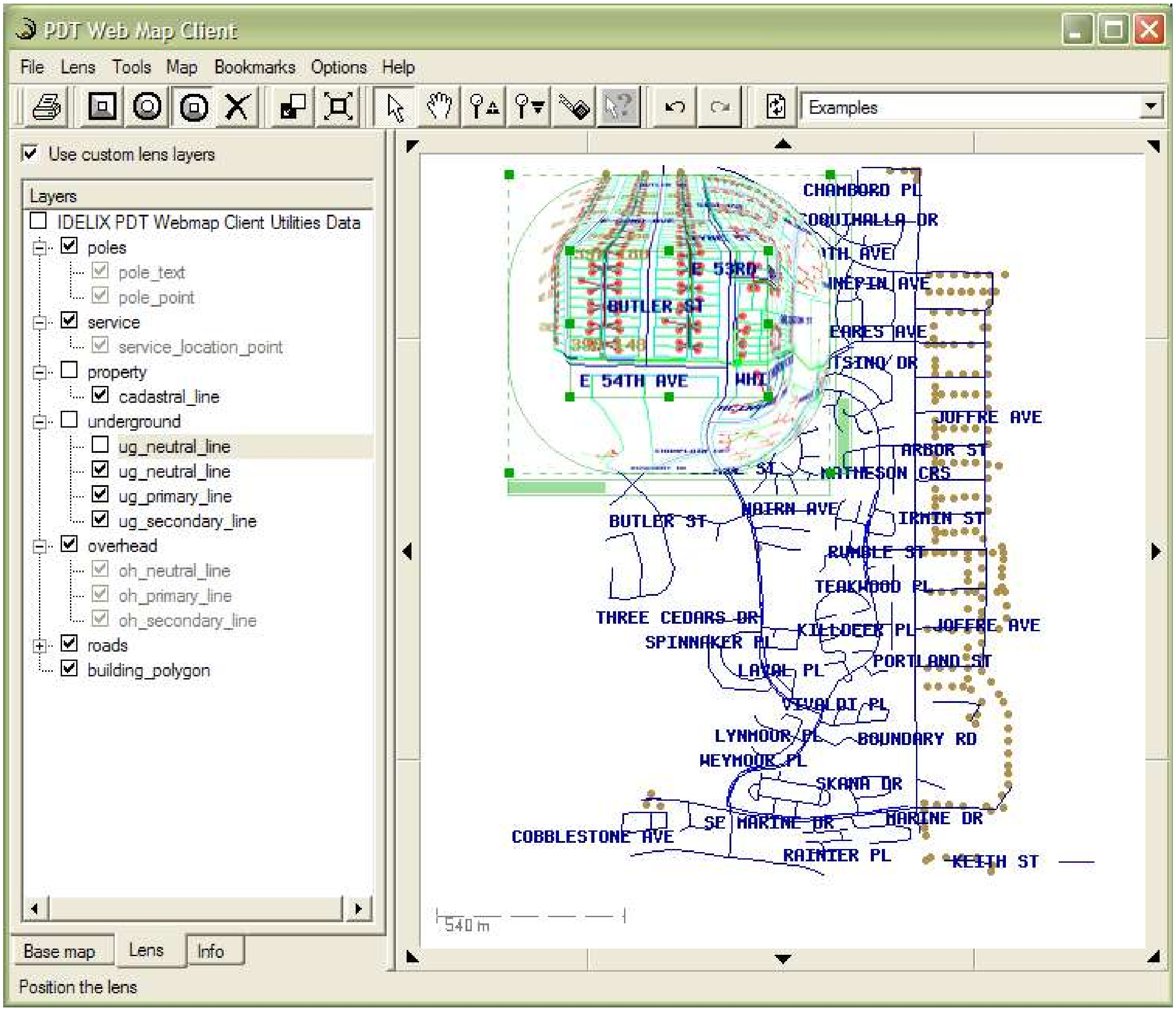
Trails

y to drive a PDT lens to automatically and sequentially traverse an image over a prescribed path. If desired, a shaded snail s has been and the image (including the snail trail) can be saved so that the user may return to the image at a later date to

bology. In order for the user to obtain the situational awareness of the battle theatre the map is typically zoomed out to a large ymbols are clustered very closely together and often overlap each other as well as occlude parts of the map image. By nap of smaller scale (for example, 1:50,000). The symbols are now placed on the smaller scale map thus reducing the visual

nd Transparency

ap viewer by linking data layer selection to data layer visibility within the PDT lens. This can be accomplished by creating user ed to data layers displayed on a GIS map (see Figure 6 below).



pling of data visible outside the lens with data visible inside the lens. As such, the PDT lens can be used to de-clutter the he second is the ability to blend layers, with varying degrees of layer transparency, to allow for better interpretation of the ap while a second layer was a geo-rectified image of the location, a user would be able to more quickly and precisely locate cy adjustments were provided.

d GIS, to collaborate in real time. A lens placed on one occurrence of the GIS can be automatically placed on a second a a TCP/IP based network. For details of enablement, see the section 4 discussions on synchronization approaches and

a Collaboration Tabletop

porting remote collaboration. However, local collaboration can be equally important. As previously mentioned, standard ople gathering around discussing some topic. In such a situation, it is better to have a large display of some type, either a se devices driven by some direct interaction such as a pen, a stylus, or some tactile input, and it is desirable for the system to ures all serve to simulate the equivalent functionality of a whiteboard or paper map. Such devices currently exist, one being Labs. It is proposed that we identify the functionality within COPlanS that would benefit most from supporting naturally co- n an appropriate device.

jected, gesture-based, light table called the DiamondTouch Table (see Figure 7 below). The DiamondTouch (DT) Table is a ouch events on an individual user basis. This ability makes the DT Table a very useful device in the area of human-computer

ns embedded in the touch surface. Each antenna transmits a unique signal. When a user touches the surface, the antennas rough the user's body to a conductive pad on the user's chair.

e on a single surface.

e way to interact with geo-spatial data.

can be deployed into a forward command and control situation.

le has no effect on a users input actions).

red with projector, stand, carrying cases etc).

ve aspect involving multiple users and where one (or more) large, shared display surfaces can be beneficially used. Typically iplines must come together in order to produce a high quality output. The team can be gathered around a single DT Table or ble. Given the capability of the DT Table, it is well suited to be used in the following environments and applications:

ware applications available. The only software applications that exist are several basic programs that demonstrate some of e insight to the possibilities of using the DT Table in a military environment they do not provide sufficient functionality to be field signed from inception to support multiple simultaneous users and accept multi handed gestures as input.

e. This application ingests JPEG imagery and displays it on the table. Using two fingers, one from each hand, a user can As the user separates their fingers, the PDT lens can be sized. The users' finger is then used to move the le ns around the ens. The user can also select a pen and annotate a region of interest by drawing on the table with a finger.

given the fact there are no commercially deployable table aware (gesture-based, multi-user) applications available, we he benefits that a DT Table with appropriate software can offer. Given the target users and use scenarios identified earlier in

out device (such as the DT Table). As a result there is an inherent risk associated with the implementation of such an zation technologies, as well as geo-spatial expertise, this risk can be mitigated.

able aware application be used. The first phase should be aimed at developing an initial prototype table aware application that esired functionality can be obtained and documented. Only then will it make sense to develop a more complete prototype or nd users and thoroughly evaluated in order to fully understand the potential benefits prior to finalizing any subsequent

s possible to run existing PC applications on the table and use a mouse paradigm as an input device, the true benefits of the for dual hand based gesture inputs from a user and almost all software programs do not allow multiple simultaneous users to , a table). What is required is a multi-user application that allows the use of hand gestures in order to fully exploit the

.).

aster data in common file formats.

- Straight Line – distance is measured in a straight line by defining a start and stop point.
- Polygon – distance is measure by following a polygonal path defined by the user.

7.2.6.7. Tool Bars

- Tool bars should be modular with logical functions grouped together.
- Each user should be able to detach a tool bar of choice and position it as desired on the table.
- The tool bars should be colour coded so that they can be associated with each user.
- A later version of the application could have toolbars that can orient as appropriate to the position of the user, but this is challenging to implement in common development frameworks and will require additional effort.

7.2.6.8. Layers and Transparency

- Be able to ingest multiple files and display two of the files as layers.
- Be able to define what file is displayed inside the lens and what file is displayed outside the lens.
- Be able to change the transparency of the layers within the PDT lens.

7.2.6.9. Remote Collaboration

- The application should support collaboration between 2 (or more) geographically dispersed tables that are connected via an IP based data link.
- It should be possible to pass control from one table to another table at the option of a moderator.
- Actions on the control table should be copied on the remote table. This should include annotation and mensuration as well as PDT lens configuration and movement.

7.2.6.10. Calibration

The application should have a calibration routine bundled or built in so that the table can be calibrated.

8. Enhancing the Visual Diagramming Components of COPlanS

This section examines the potential for enhancing the visual diagramming components of the COPlanS application.

8.1. Workflow Management

The Workflow Diagram component of COPlanS (created using the JViews visual diagramming tool from ILOG) is currently used to create, display and manage relatively simple process workflows (see Figure 8 below). However, the potential for the creation of significantly more complex workflows does exist. Workflow diagrams for complex decision paths can quickly grow to a level where it is impractical or impossible to display the entire structure in a single window. In such cases users typically choose zooming and panning tools to view a portion of the diagram at a "readable" scale. This often results in inefficiencies and a loss of situational awareness as important information is pushed off the screen.

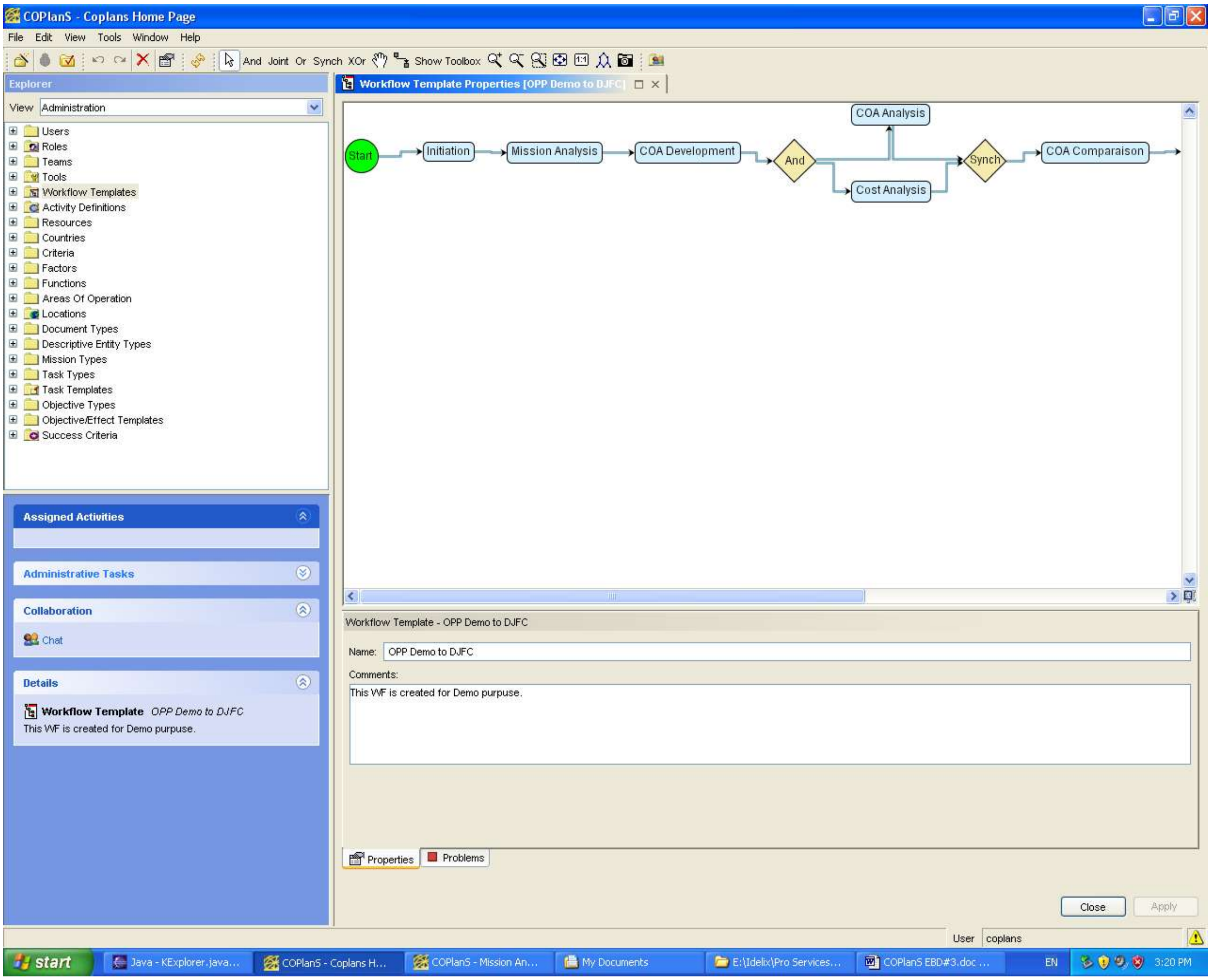


Figure 8 – Typical Workflow Diagram in COPlanS

Also, as stated in the DRDC fact sheet (IS-228-A), the new version of COPlanS will support multi-level workflows where planners will be able to define activities which in themselves are workflows involving a subset of activities. The ability to capture conditional workflow processes is also being considered.

8.2. Mission Analysis

The Effect Based Diagram component of COPlanS (created using the JViews visual diagramming tool from ILOG) is currently used to display and modify relatively complex process workflows (see Figure 9 below) used for detailed mission analysis. In such cases users typically choose zooming and panning tools to view a portion of the diagram at a "readable" scale. This often results in inefficiencies and a loss of situational awareness as important information is pushed off the screen.

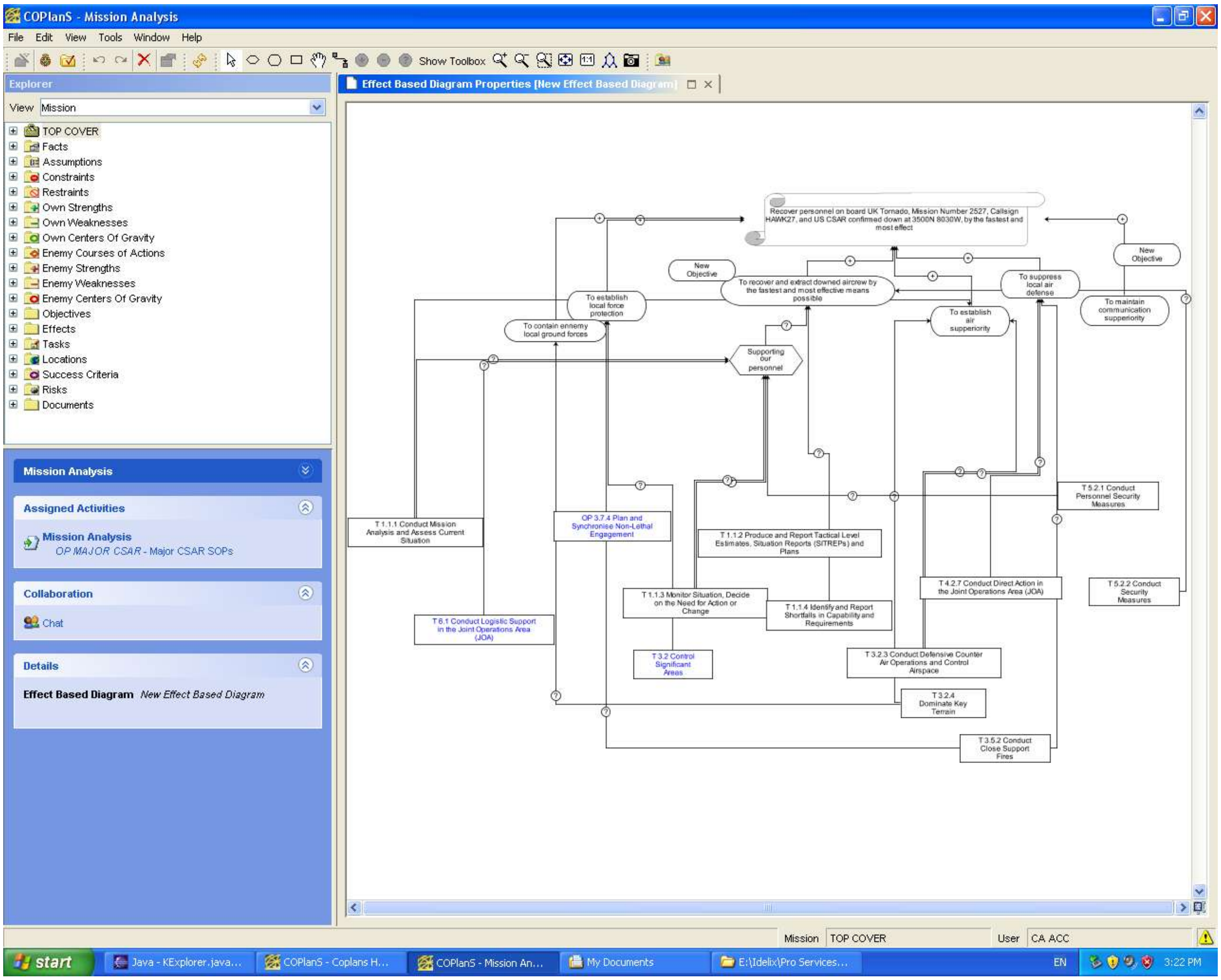


Figure 9 – Typical Effect Based Diagram in COPlanS for Mission Analysis

8.3. Order of Battle (ORBAT) Asset Visualization

The ORBAT (Order of Battle) browser in COPlanS (created using the JViews visual diagramming tool from ILOG) allows commanders to visualize and formulate analysis about the assets and resources available to them for a given task (see Figure 10 below). Similar to Workflow Diagrams, ORBAT charts can become complex and difficult to view in their entirety on computer screens.

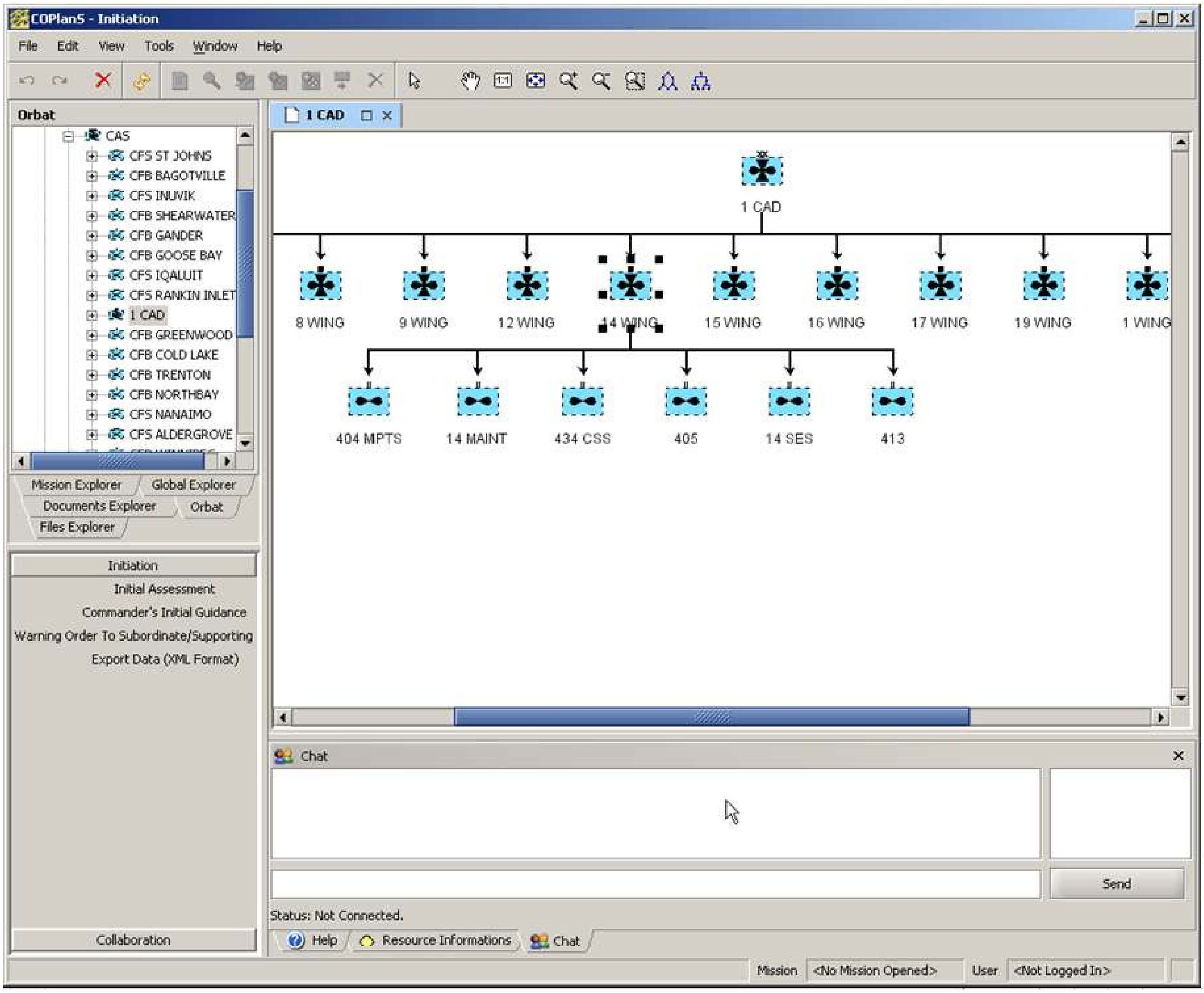


Figure 10 – Typical ORBAT Chart in COPlanS

8.4. Detail-in-Context for Visual Diagramming in COPlanS

Several components of COPlanS, specifically the Workflow Diagrams, the Effect Based Diagrams, and the ORBAT Charts display a network of discrete data elements connected by logical relationships. Logical relationships are communicated to the user visually, using position and connecting symbols such as arrows. This data is inherently different from the type of data usually associated with PDT enabled applications. Typical PDT applications deal with continuous data where positional relationships are inherent in the data. For example, map data is continuous, and objects on the map have real-world positions. In an ORBAT chart, however, the relationship of different components is purely logical, and how those relationships are shown is up to the display process.

While detail-in-context rendering can have a significant positive impact in viewing discrete networks of abstract data, PDT is not the ideal detail-in-context approach. Rather, it is suggested that a detail-in-context approach designed from the ground up for viewing of networks of discrete logically related data be employed. Rather than magnifying data in a continuously varying manner, the technique would magnify individual objects independently without distorting any one discrete object. Logical connections, represented by lines or arrow, would not be distorted but would instead simply have their start and end-points moved to accommodate reshaped objects. There have been several techniques similar to the one described developed in the academic community. The differences between the techniques mostly have to do with how objects are moved about the screen, if at all, and how much objects are magnified, depending on their relationship to the object of interest.

Perhaps the most challenging part of the proposed work would be to determine which technique would be most appropriate for COPlanS. This may be further complicated by the fact that the ORBAT charts, being hierarchical data sets, may benefit from a different detail-in-context approach than the other components. Hierarchies are a specialized subset of general network graphs and detail-in-context algorithms can be fine tuned to suit this special case.

9. Rough Order of Magnitude (ROM) Estimates by Feature

This section provides rough order of magnitude (ROM) estimates of the effort required to implement various collaboration and data visualization features mentioned in the preceding discussions. These estimates are provided for comparison purposes only.

9.1. General Visual Collaboration

9.1.1. Visual Highlighting Approaches for Multiple Users

9.1.1.1. Remote Cursors

- Level of Effort: Low
- Risk: Medium
- Payoff: Medium
- **Priority: Medium**

9.1.1.2. Multi-User Radar View

- Level of Effort: Medium
- Risk: Medium
- Payoff: Medium
- **Priority: Medium**

9.1.1.3. Awareness Lenses

- Level of Effort: High
- Risk: High
- Payoff: High
- **Priority: Medium**

9.1.1.4. Universal Annotation

- Level of Effort: High
- Risk: Medium
- Payoff: High
- **Priority: High**

9.1.1.5. Central Note Board

- Level of Effort: Medium
- Risk: Low
- Payoff: Medium
- **Priority: Medium**

9.1.2. Synchronization Approaches for Two Users

9.1.2.1. Multi-User Master/Slave Synchronization – Dumb Display Host

- Level of Effort: Medium
- Risk: Low
- Payoff: Medium
- **Priority: High**

9.1.2.2. Multi-User Master/Slave Synchronization – Application Synchronization

- Level of Effort: High
- Risk: Medium-High
- Payoff: Medium
- **Priority: Low**

9.1.2.3. On-Demand Synchronization

- Level of Effort: Medium
- Risk: Medium
- Payoff: Low
- **Priority: Low**

9.2.

9.3. PDT in the COPlanS GIS (Note: Assumes access to GIS source code)

- Level of Effort: Medium
- Risk: Low
- Payoff: High
- **Priority: High**

.1. PDT Lens Providing Focus plus Context

Level of Effort: Low

Low

High

High

ssisted Functionality

Low

v

High

g Map

oration Tabletop (Note: Assumes access to table aware GIS application source code)

9.5.

9.6. Enhancing the Visual Diagramming Components of COPlanS

9.6.1. Enhancement of Workflow Diagrams

- Level of Effort: TBD
- Risk: TBD
- Payoff: TBD
- **Priority: TBD**

.2. Enhancement of Effect Based Diagrams (Mission Analysis)

Level of Effort: TBD

TBD

TBD

TBD

cement of ORBAT Charts

TBD

D

TBD

odels

roposed and properly integrate PDT into an existing application, the integrator must have access to the image rendering ation. While this type of integration is not necessarily difficult it must be done with full access to the image processing pipeline tion. This is an area that third party developers have not traditionally had access to. Given this background, the following entified and will be referred to later in this report.

ired Functionality

original author of the application, integrates PDT using the SDK. Since the OEM owns the source code they have access to application in order to properly integrate PDT. The obvious benefit of this model is that the architecture and implementation completely understood. The downside is that the OEM must first develop a detailed understanding of PDT and then define ation. As PDT is a relatively new technology and most OEMs have not yet been exposed to it, IDELIX feels, with some recent s results in a less than optimal implementation.

o the Image Processing Pipeline; IDELIX Integrates

s to the image-processing pipeline. Once the APIs are made available, IDELIX can proceed with the integration of PDT. The that the OEM retains control of its product and does not need to expose its' source code to an external integrator. If ed, it is expected that the resulting integration would be of high quality. However, given the extensive effort involved to both erfaces and subsequently implement PDT through those interfaces, it is expected that this model would be relatively expensive

tly Integrate Required Functionality

work together to integrate PDT into the target application. Access to the source code is provided to IDELIX with the resulting eting the initial requirements and expectations. The primary issue here is usually cost since two companies must assign -located geographically to be most effective. The resultant travel and living expenses can be a significant additional cost to re is often an overlap of duties between the two organizations that can increase integration costs further.

quired Functionality

s to the OEMs source code and performs all integration of PDT into the target application. This is a model that IDELIX has t. For example, this method was used for the integration of PDT into ITT's Rapid Access Image Viewer (RAIV) and Mobile /) clients. Included in this model is the provision of time for IDELIX to transfer to the OEM the knowledge of how PDT was ion. This is typically done by providing both SDK related training and a detailed code review explaining where and how PDT ne OEM software. Once the OEM has received this training they are fully capable of maintaining the code base while IDELIX o support the OEM on an ongoing basis. However, there is a significant risk with this option in that an OEM vendor may be ce code with IDELIX as this code may contain part or all of their core intellectual property.

tegrator Integrates Required Functionality

tegrator is given access to the OEM's source code and performs all integration of PDT into the target application using the main issue with this implementation option is that an appropriate third party vendor, one that is familiar with both the base K, may be difficult to find. Also, as stated previously, the OEM vendor may be unwilling to share their source code with the

Application to Specification

w application that is both compliant with the required functionality, as defined by the customer, and has integrated PDT e of this model is that one organization has control over the development of both the core functionality and the integrated PDT the organization that will be the most familiar with the PDT SDK and its implementation challenges.

tegrator Produces an Application to Specification

ntegrator produces a new application that is both compliant with the required functionality, as defined by the customer, and ality. The advantage of this model is that one organization has control over the development of both the core functionality and

[1] OEM is the Original Equipment Manufacturer. In the case of software the OEM is defined as being the writer of the software.

ality. Again, the main issue with this implementation option is that an appropriate third party integrator, one that is familiar with chnology and the PDT SDK, may be difficult to find.

11. Rough Order of Magnitude (ROM) Estimates by Implementation Model

This section provides rough order of magnitude (ROM) estimates of the effort required to implement PDT based on the models presented in the previous section. These estimates are provided for comparison purposes only since the actual effort required to implement PDT is highly dependent on the conditions of integration and the feature set selected.

11.1. General Visual Collaboration

11.1.1. Multi-User Master/Slave Synchronization for 2 Users – Dumb Display Host

11.1.1.1. OEM (Call-Fusion, Webex, etc.) Integrates Synchronization Functionality

- Pros:
  - Vendors are very experienced with this type of synchronization
- Cons:
  - Secure deployments can be relatively expensive
- Level of Effort: Medium
- Risk: Low-Medium
- Payoff: Medium
- **Priority: Medium**

11.1.1.2. OEM Provides APIs; IDELIX Integrates

- This option should be considered since synchronization is not an IDELIX core competency

11.1.1.3. OEM and IDELIX Jointly Integrate Functionality

- This option should not be considered since synchronization is not an IDELIX core competency

11.1.1.4. IDELIX Integrates

- This option should not be considered since synchronization is not an IDELIX core competency

11.1.1.5. Third Party System Integrator Integrates Functionality

- This option should not be considered since this type of synchronization is likely not a core competency

11.1.1.6. IDELIX Produces an Application to Specification

- This option should not be considered since synchronization is not an IDELIX core competency

11.1.1.7. Third Party System Integrator Produces an Application to Specification

- This option should not be considered since this type of synchronization is likely not a core competency

11.1.2. Multi-User Master/Slave Synchronization for 2 Users – Application Synchronization

11.1.2.1. OEM (Thales) Integrates Synchronization Functionality

- Pros:
  - Thales familiar with code since developed application
- Cons:
  - Application synchronization is very difficult
- Level of Effort: High
- Risk: High
- Payoff: Low
- **Priority: Low**

11.1.2.2. OEM Provides APIs; IDELIX Integrates

- This option should not be considered since synchronization is not an IDELIX core competency

11.1.2.3. OEM and IDELIX Jointly Integrate Functionality

- This option should not be considered since synchronization is not an IDELIX core competency

11.1.2.4. IDELIX Integrates

- This option should not be considered since synchronization is not an IDELIX core competency

11.1.2.5. Third Party System Integrator Integrates Functionality

- Cons:
  - Application synchronization is very difficult
- Level of Effort: High
- Risk: High
- Payoff: Low
- **Priority: Low**

11.1.2.6. IDELIX Produces an Application to Specification

- This option doesn't make sense

11.1.2.7. Third Party System Integrator Produces an Application to Specification

- This option doesn't make sense

11.2.

11.3. PDT in the COPlanS GIS

11.3.1. PDT Enhancement of On-Map Mission Planning

- Level of Effort: Varies
- Risk: Varies
- Payoff: High
- **Priority: High**

3.1.1. OEM (Luciad) Integrates PDT Functionality

Pros:
  - GIS application architecture and code known well by OEM vendor
- Cons:
  - OEM vendor may choose not to participate
  - Conflicting priorities in application development cycle for OEM vendor; could be hidden delays
  - OEM vendor has no knowledge of PDT
- Level of Effort: Med-High
- Risk: High
- Payoff: High
- **Priority: Low**

11.3.1.2. OEM (Luciad) Provides APIs to the Image Processing Pipeline; IDELIX Integrates PDT

- Pros:
  - IDELIX can provide PDT knowledge and expertise to the development effort
  - More time flexibility for the customer since defined project stages
- Cons:
  - OEM vendor may choose not to participate
  - Highly conflicting priorities in application development cycle for OEM vendor; hidden delays likely
  - Multiple vendors to deal with
- Level of Effort: High
- Risk: Med-High
- Payoff: High
- **Priority: Low**

11.3.1.3. OEM (Luciad) and IDELIX Jointly Integrate PDT Functionality

- Pros:
  - IDELIX can provide PDT knowledge and expertise to the development effort
  - Maximum understanding and knowledge applied to development effort

- Cons:
  - OEM vendor may choose not to participate
  - Conflicting priorities in application development cycle for OEM vendor; could be hidden delays
  - Multiple vendors to deal with
- Level of Effort: Med-High
- Risk: Med
- Payoff: High
- **Priority: Med**

11.3.1.4. IDELIX Integrates PDT Functionality

- Pros:
  - IDELIX can provide maximum PDT knowledge and expertise to the development effort
- Cons:
  - High risk since OEM vendor may choose not to share their source code
- Level of Effort: Low-Med
- Risk: Med-High
- Payoff: High
- **Priority: High**

11.3.1.5. Third Party System Integrator Integrates PDT Functionality

- Cons:
  - Depends on experience with Luciad GIS
  - Depends on experience with PDT
  - High risk since OEM vendor may choose not to share their source code
- Level of Effort: High
- Risk: High
- Payoff: High
- **Priority: Very Low**

11.3.1.6. IDELIX Produces an Application to Specification

- Pros:
  - Single source Canadian vendor
  - Purpose built application will provide maximum usability
  - Highest degree of control over development process
  - No legacy code to contend with
- Cons:
  - Removal of current OEM vendor GIS application
- Level of Effort: Med-High
- Risk: Med
- Payoff: High

- **Priority: Med**

11.3.1.7. Third Party System Integrator Produces an Application to Specification

- Pros:
  - Single source vendor
  - Purpose built application will provide maximum usability
  - Highest degree of control over development process
  - No legacy code to contend with
- Cons:
  - Removal of current OEM vendor GIS application
- Level of Effort: Med-High
- Risk: Med-High
- Payoff: High
- **Priority: Med-High**

11.4.

11.5. PDT in the COPlanS GIS Operating on a Collaboration Tabletop

11.5.1. Software Functionality Implementation for a Table Aware Application

- Level of Effort: Varies
- Risk: Varies
- Payoff: High
- **Priority: High**

5.1.1. OEM Integrates Functionality

This option cannot be considered since there are no current GIS OEM applications for the MERL table

2.OEM Provides APIs to the Image Processing Pipeline; IDELIX Integrates

ption cannot be considered since there are no current GIS OEM applications for the MERL table

EM and IDELIX Jointly Integrate Functionality

tion cannot be considered since there are no current GIS OEM applications for the MERL table

Integrates Functionality

cannot be considered since there are no current GIS OEM applications for the MERL table

arty System Integrator Integrates Functionality

not be considered since there are no current GIS OEM applications for the MERL table

duces an Application to Specification

- Single source Canadian vendor
- Purpose built application will provide superior usability
- High degree of control over development process
- No legacy code to contend with

- Cons:
  - Removal of current OEM GIS application
- Level of Effort: Medium
- Risk: Medium (3 phased approach only)
- Payoff: High
- **Priority: Medium**

11.5.1.7. Third Party System Integrator Produces an Application to Specification

- Pros:

- Single source vendor
- Purpose built application will provide superior usability
- High degree of control over development process
- No legacy code to contend with

- Cons:
  - Removal of current OEM GIS application
- Level of Effort: Medium
- Risk: Medium (3 phased approach only)
- Payoff: High
- **Priority: Medium**

12.Points of Contact

The following are business and technical points of contact (POC) from IDELIX.

12.0.1. Business Contacts

Doug Fraser VP, Business Development
IDELIX Software Inc.
555 – 1122 Mainland St.
Vancouver, BC
Canada V6B 5L1
tel 604.656.6305
fax 604.656.6310
dfraser@idelix.com

Terry McColl VP, Professional Services
IDELIX Software Inc.
555 – 1122 Mainland St.
Vancouver, BC
Canada V6B 5L1
tel 604.484.2895
fax 604.656.6310
tmccoll@idelix.com

12.0.2.

12.0.3. Technical Contacts

Garth Shoemaker Director of Research
IDELIX Software Inc.
555 – 1122 Mainland St.
Vancouver, BC
Canada V6B 5L1
tel 604.656.6306
fax 604.656.6310
gshoemaker@idelix.com

David Baar Chief Technology Officer
IDELIX Software Inc.
555 – 1122 Mainland St.
Vancouver, BC
Canada V6B 5L1
tel 604.656.6302
fax 604.656.6310
dbaar@idelix.com

Distribution list

INTERNAL:

2- Document Library

1- Alain Bouchard

1- Dr Adel Guitouni

1- Normand Pageau

1- LCol Jean-Guy Levesque

1- Denis Gouin

EXTERNAL:

1- DRDKIM

DOCUMENT CONTROL DATA

1. ORIGINATOR (name and address) Defence R&D Canada Valcartier 2459 Pie-XI Blvd. North Val-Bélair, QC G3J 1X8	2. SECURITY CLASSIFICATION (Including special warning terms if applicable) Unclassified

3. TITLE (Its classification should be indicated by the appropriate abbreviation (S, C, R or U)
Feasibility Study of Integrating IDELIX's Pliable Display Technology into the COPlanS Technology Demonstration Software

4. AUTHORS (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)
IDELIX Software Inc.

5. DATE OF PUBLICATION (month and year) March 2005	6a. NO. OF PAGES 41	6b .NO. OF REFERENCES 0

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. Give the inclusive dates when a specific reporting period is covered.)
Contractor Report

8. SPONSORING ACTIVITY (name and address)

9a. PROJECT OR GRANT NO. (Please specify whether project or grant) 13du	9b. CONTRACT NO. W7701-4-4911
10a. ORIGINATOR'S DOCUMENT NUMBER CR 2005-075	10b. OTHER DOCUMENT NOS N/A

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

- ☒ Unlimited distribution
- ☐ Restricted to contractors in approved countries (specify)
- ☐ Restricted to Canadian contractors (with need-to-know)
- ☐ Restricted to Government (with need-to-know)
- ☐ Restricted to Defense departments
- ☐ Others

12. DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in 11) is possible, a wider announcement audience may be selected.)

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

This document examines the potential for enhancement of Defence Research and Development Canada's Collaborative Operations Planning System (COPlanS) technology demonstration software in the areas of collaboration and data visualization using IDELIX's Pliable Display Technology. In particular, it begins by outlining several possible forms of general collaboration that apply to the application and then defines a number of areas within the application with collaboration and data visualization improvement potential. Each of these areas is subsequently analyzed in depth with specific details of how enhanced collaboration and data visualization can be attained with PDT. Finally, rough orders of magnitude are provided for all defined features and potential implementation approaches.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

collaboration, data visualization, pliable display technology, collaborative tabletops